which was given an excellent account of the Clyde islands. Contemporary with Macculloch was another observer to whom Scottish geology stands deeply indebted, Ami Boué. After taking his degree in Scotland Boué went to Paris, where for a time he employed himself in preparing his "Essai géologique sur l'Écosse," which saw the light in the year 1820. A few native inquirers began to make their appearance during the closing years of the eighteenth and the early decades of the nineteenth century as pioneers in the investigation of the details of the local geology. First came David Ure, whose excellent "History of Rutherglen and East Kilbride," published in 1783, stands out pre-eminent for the fulness and faithfulness of its descriptions. Afterwards came Andrew C. Ramsay. After referring to the work of John Craig in Lanarkshire, Montgomery in Renfrewshire, Prof. Thomas Thomson in Glasgow University, and James Bryce, Sir Archibald Geikie said that of all the influences which conspired to raise in Glasgow an interest in the geological history of the district he was disposed to give the foremost place to that of James Smith, of Jordanhill.

THE WINNIPEG MEETING OF THE BRITISH ASSOCIATION.

A CIRCULAR has been prepared containing information of interest to members of the British Association who propose to attend the meeting to be held in Winnipeg, Manitoba, Canada, in August next, under the presidency of Sir J. J. Thomson, F.R.S. A representative local executive committee and officers have been appointed to conduct the local arrangements, which will include some interesting excursions and facilities for a tour through the Western Provinces to the Pacific Coast. The weather conditions during the latter part of August and the beginning of September are favourable in the Western Provinces of Canada, whilst in Winnipeg, situated 760 feet above sea-level, the days are warm, though not oppressively hot, and the nights are invariably cool. On account of August being the busiest month of the year in bookings to America, no reduction on minimum steamship rates will be made to members of the association, but superior accommodation may be granted, on the return voyage, at the ordinary minimum rate. The journey to Winnipeg, the meeting, and return home will take about thirty-two days. There will be a western excursion from Winnipeg to Regina, Moose Jaw, Calgary, Edmonton, Vancouver, and Victoria, and return to Winnipeg; members who take part in this excursion will require ten more days, thus making a six weeks' visit. Special fares are expected to be in force on the Canadian railways, amounting probably to a single fare for the return journey, from Montreal to Winnipeg, provided the party numbers not less than fifty; as also from Winnipeg to Vancouver, or for any side-trip made by individual members. The estimated personal expenditure of each member attending the meeting from Great Britain is a minimum of about 38*l.*, and an average of about 65*l.* The additional expense of the western excursion will be about 25*l.* Any member of the association who contemplates an extensive journey of exploration or for other scientific purposes, fishing, hunting, &c., is invited to communicate with the local secretaries of the British Association, University of Manitoba, Winnipeg. Expert advice and assistance will be given to any group of members who propose to avail themselves of this opportunity. A list of hotels and lodgings will be issued by the Winnipeg executive officers, to whom application should be made, early in July.

Members who propose to attend the meeting should send in their names to Mr. H. C. Stewardson, assistant treasurer of the British Association, Burlington House, London, W., not later than May 31, by which date members should, if possible, complete their arrangements with the steamship companies, as all the best accommodation on steamers sailing in August is booked some months ahead. An illustrated handbook of preliminary information, issued by the Winnipeg executive committee, will be forwarded from the office of the association on receipt of $2\frac{1}{2}$*d.* for postage.

MECHANICAL FLIGHT.[1]

Present Position.

THE recent records made by Messrs. Wright, Farman, Delagrange, and Bleriot, together with the gradual accumulation of testimony in favour of mechanical flight, have finally disabused both the public and experts of the notion that aviation is a dream.

Many engineers from time immemorial have tackled the subject without success, and there was every reason for the sceptical attitude which has prevailed until the last few years. It is now evident that mechanical flight was impossible before science and engineering skill in the nineteenth century had so perfected the heat engine that considerable power was obtainable with but little weight. The present improved aspect of affairs must not, however, blind us to the fact that much has yet to be done. The most successful machines now in existence show serious defects, cannot be manipulated in troublesome weather, and have every part so light that at all times they are on the brink of collapse. It rests with mechanical engineers to design a stronger machine without losing efficiency. In the course of this paper the author proposes to indicate certain points in which improvement is desired, and at the same time he has endeavoured to include a sufficiency of the theoretical and experimental knowledge available on the subject to enable a would-be aviator to construct a simple type of machine.

It cannot be too strongly realised that existing information is defective, and a few words as to research may be useful.

Necessity for Research.

It will be shown in the course of this paper that the whole question of mechanical flight depends upon a knowledge of the manner in which air reacts against solid bodies moving through it. A large number of researches have been made during the past 150 years, but even yet exact information is lacking on the majority of points.

Furthermore, mathematical analysis has not been sufficiently developed. A few great mathematicians (including Lords Kelvin and Rayleigh) have devoted some attention to the matter, but the author is not aware that any mathematician worthy of the name has considered it worth while to make an exhaustive study of the question, although it must be recognised that the recent advances in the theory of hydrodynamics form useful auxiliaries to the study of aërodynamics.

Brief History of the Theory.

The nature of fluid resistance has been investigated for many years, and the general principles are to be found in Newton's "Principia." The ballistic researches of Hutton and Robins at the end of the eighteenth century first clearly showed the quantitative value of air resistance, and their work is still valuable. On the hypothesis deducible from Newton's work, Messrs. Navier and Gay-Lussac early in the nineteenth century formulated a theory of flight which showed that great power was necessary, and this notion held sway for many years after, so that little progress was made with the subject, flight being deemed impracticable. Experiments by Wenham and Browning in the 'eighties, together with Langley's researches in America and Maxim's in England, clearly showed the fallacy of this idea. Pénaud in 1876 first gave the mathematical theory of the aëroplane, which had been conceived by Henson in 1840. The late Mr. Froude, Lord Rayleigh, and Prof. Bryan developed this theory, and in 1903 the last-named produced equations of stability for the aëroplane. Two years later Captain Ferber, of the French artillery, amplified these equations to find the conditions of lateral stability and the form of the trajectory, and quite recently Mr. Lanchester has done similar work. Prof. Fitzgerald and Lord Rayleigh have given some attention to the ornithoptère, and Profs. Pettigrew and Marey at an earlier date arrived at several important conclusions respecting bird flight. The helicoptère has not received very much attention, but the cognate work of the late Mr. Froude and his son on propellers has a most important bearing on the matter. Mr. Alexander, Sir Hiram Maxim, and several other engineers have made researches on the subject of air-propellers.

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[1] Abridged from a paper by Mr. Herbert Chatley read before the Society of Engineers on December 7, 1908.

Theory.

Resistance of Surfaces and Solids.[1]—A certain resistance is experienced when any body is moved through the air, depending on the form of the body and the relative speed. If the air is abruptly parted the sudden alteration of its relative momentum causes a thrust on the body; its friction against the body produces further resistance, and the partial vacuum at the rear (due to the air not immediately returning) causes still more resistance. The air enters this rear space in a series of whirls or eddies, the kinetic energy of which must be supplied by the moving body. Hence we must consider the front form, the surface, and the rear form of the moving body. All the effects are, at the speeds commonly occurring, nearly proportional to the square of the speed.

If a thin but rigid plane be moved perpendicularly to itself with a speed of V feet per second, it will be subjected to a dynamic resistance and also to a negative pressure due to the whirling behind. The skin resistance will be negligible except when the dimensions are very great. The dynamic resistance depends on the quantity of air affected, which again varies with the area, so that we may write

$$P=k\left(1+\frac{1}{n}\right)SV^2 \quad . \; . \; . \; . \; . \; . \quad (1)$$

where P is the total pressure in lb., S is the area in square feet, V the speed in feet per sec., and k and n are constants; k is the mass of a cubic foot of air divided by 2, and is equal to about 0·0012 at normal temperature and pressure; n is the ratio of the dynamic to the negative pressure, and is generally rather more than 2, so that $k\left(1+\frac{1}{n}\right)$ varies according to different experimenters from 0·0013 to 0·0017. Langley's value 0·0017 is frequently used, so that we have

$$P=kSV^2 \text{ (where } k=0{\cdot}0017) \quad . \; . \; . \; . \; . \quad (2)$$

If the plane be turned so that it make an angle γ with the direction of motion, the dynamic action is no longer symmetrical, skin friction becomes important, and negative pressure decreases. Many rules have been given for this case, but except for very small (say less than 2°) and very large angles (more than 40°) the following rule will serve:—

$$P=2kSV^2 \sin\gamma \quad . \; . \; . \; . \; . \; . \; . \quad (3)$$

As the surface becomes nearly coincident with the direction of motion P decreases, but there is a certain residual resistance due to edge dynamic action and skin friction. Lanchester makes this approximately

$$F=\frac{2kSV^2}{20} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (4)$$

where F is the total resistance in lb.

(The author is responsible for this formula.)

This means that the coefficient of skin friction is upwards of 5 per cent. of the coefficient of resistance. There is some difference of opinion as to this, but the value will serve.[2]

Curved surfaces experience analogous resistances when inclined so as to present a *definite* convexity or concavity forwards, the coefficient being rather larger. If such surfaces have their chords in the direction of motion, they will be subject to skin friction, and will also experience an upward or downward thrust according as the convexity is beneath or above, provided that the curvature is easy so that the air may stream into the concavity. Surfaces laterally great experience more thrust than those the major dimensions of which are in the direction of motion, the ratio of thrust per unit area varying about 30 per cent. above and below that on a square surface.

The resistance of air to solids in motion is similar to that of water, but in the decreased ratio of the density of air to water (about 1 : 800).

Centre of Pressure.

The dynamic resistance is not symmetrical, the resultant pressure being ahead of the centre of area. More information is required as to this displacement. For planes inclined at an angle γ to the direction of motion, the following rule, given by Joëssel and Avanzini, is much used:—

$$\Delta=0{\cdot}3(1-\sin\gamma)L \quad . \; . \; . \; . \; . \; . \; . \quad (5)$$

where Δ is the distance in feet from the centre of area to the centre of pressure, and L the length in feet of the plane in the direction of motion.

Turnbull (*Phys. Review*, xxiv., March, 1907) contests this rule, and states that his experiments indicate that when γ is less than 18°, Δ simply varies with γ, so that when $\gamma=0$, $\Delta=0$. For surfaces having a convex underside or concavity in front and convexity at the rear (both on the underside), he gets a law similar to, but in excess of, Joëssel's. He maintains that these two types of surface only are stable.

As this quantity enters into all the stability formulæ, further experiment is urgently required.[1]

Energy Required for Flight (Aëroplane).

Since the normal pressure varies as the area of the plane and the square of the speed, the component of this in the direction of motion will similarly vary. Thus if the thrust is in the direction of motion we have R the resistance of the plane in lb.

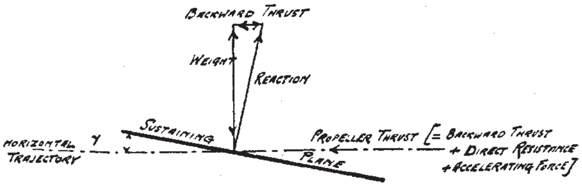
BACKWARD THRUST
WEIGHT
REACTION
SUSTAINING
PLANE
HORIZONTAL TRAJECTORY
γ
PROPELLER THRUST [= BACKWARD THRUST + DIRECT RESISTANCE + ACCELERATING FORCE]

FIG. 1.—Equilibrium of Forces in Aëroplanes: Aëroplane Running Horizontally.

$$R=P\sin\gamma=2kSV^2\sin^2\gamma \quad . \; . \; . \; . \; . \; . \quad (6)$$

and if a further resistance CV^2 be allowed (where C is the projected area in square feet of the car at right angles to the direction of motion) for the car and framework, we have

$$\begin{aligned} H&=(R+CV^2)V \\ &=(2kS\sin^2\gamma+C)V^3 \quad . \; . \; . \; . \; . \; . \quad (7) \end{aligned}$$

where H is in foot-pounds per second.

Hence the power required appears to vary as the cube of the velocity. γ, however, is not necessarily constant, so that we may diminish the power by decreasing γ, always remembering that C is invariable. The limiting value of γ is determined by the weight, for the vertical thrust must never be less than the weight. If the direction of motion is horizontal, then we have

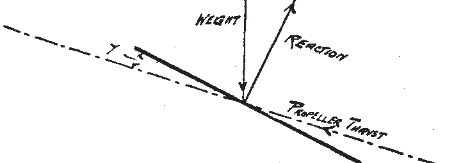

FIG. 2.—Equilibrium of Forces in Aëroplanes: Aëroplane Ascending.

$$W=P\cos\gamma=2kSV^2\sin\gamma\cos\gamma \quad . \; . \; . \; . \quad (8)$$

where W is the weight in lb., so that V being known, γ can be computed, or *vice versâ*. It will follow from this that if a certain starting value for γ is assumed, the value V, found from equation (8), will be the lowest soaring speed, *i.e.* the starting speed required.

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[1] See Lamb's "Hydrodynamics," Lanchester's "Aërodynamics," also an article by the author on the "Stream Line Theory in Relation to Aërodynamics," in *Aëronautics*, August, 1908.

[2] See Baden-Powell's "Practical Aërcdynamics," Langley's "Experiments in Aërodynamics," and the author's book, "The Problem of Flight."

[1] See Turnbull's paper, also Kummer, "Berlin Akademie Abhandlungen," 1875-6; Joëssel, "Génie Maritime," 1870; "Langley, "Experiments in Aërodynamics"; Moedebeck's "Pocket-Book."

By substitution between (7) and (8) the speed corresponding to a given power and angle may be obtained, or the power required to drive the machine at any particular angle and speed. If the machine be rising, so that the line of motion is inclined at an angle θ to the horizon, then (8) becomes

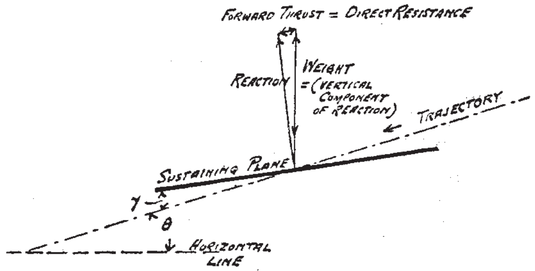
FORWARD THRUST = DIRECT RESISTANCE
WEIGHT =(VERTICAL COMPONENT OF REACTION)
REACTION
TRAJECTORY
SUSTAINING PLANE
γ
θ
HORIZONTAL LINE

FIG. 3.—Equilibrium of Forces in Aëroplanes: Aëroplane Descending (gliding).

$$W = P \cos(\theta+\gamma) = 2kSV^2 \sin\gamma \operatorname{ccs}(\theta+\gamma \quad . \quad . \quad (9)$$

By substitution between (7) and (9) we can find the power, speed, and angle in terms of one another in the new circumstances, which are the most adverse that have to be considered.

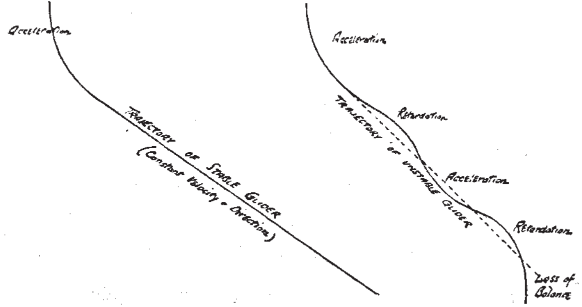
Acceleration
TRAJECTORY OF STABLE GLIDER
(Constant Velocity & Direction)
Acceleration
TRAJECTORY OF UNSTABLE GLIDER
Retardation
Acceleration
Retardation
Loss of Balance

FIG. 4.—Trajectories of Stable and Unstable Aëroplanes.

Power Required for a Helicoptère.

This will follow at once from a consideration of propeller thrust. For if T be the thrust in lb. of a propeller, under given conditions as to speed and slip, then in a helicoptère

$$W = nT \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where n is the number of propellers.

The ornithoptère will be discussed later.

Efficiency of Propellers.

Experiment has generally shown that, subject to correction for the difference of density, an air propeller is almost identical in its action with a marine propeller. The thrust is proportional to the area of the blades and the square of the speed, and the power varies as the cube of the speed. There is a diminution of thrust with a decrease of slip, and both power and thrust increase with the diameter of the propeller. There is no necessity to present here the general conclusions as to propellers, which will be found in Mr. Froude's papers in the Trans. Inst. Naval Architects, and in text-books on naval architecture and marine engineering. There is, however, one respect in which the action of a propeller in air differs from that in water, viz. the feed. Owing to the small inertia of air, a propeller, revolving on a fixed axis in air previously stationary, rapidly ejects air by axial propulsion and centrifugal force, and tends to surround itself by a vortex of air, with a consequent diminution of the thrust to almost zero. This is the reason for the lack of success in experiments which have been made on lifting screws for helicoptères. On the other hand, an axial or transverse flow caused by motion of the axis of rotation will supply the propellers with the necessary fresh air, and consequently we find that the smaller the slip (*i.e.* the greater the advance) of the screw the greater its efficiency. Similarly, in helicoptères moving laterally there is more lift.

For a sustaining screw not rising (*i.e.* with 100 per cent. slip) the author has deduced the following formula for the thrust (see "The Problem of Flight," p. 9):—

$$T = 0{\cdot}1r\sqrt[3]{HD^7} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

where T is the thrust in lb., r the revolutions per second, H the horse-power, and D the diameter in feet of the propeller. This is based on the assumption that the area is that required by the conditions as to power, diameter, and speed. The following rule for the projected area must be applied:—

$$A \doteq \frac{4}{\pi r}\sqrt[3]{\frac{H}{D^5}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where A is the ratio of the projected area to the disc area.

These rules are based on Mr. W. G. Walker's experiments with fans, particulars of which will be found in Mr. Innes's book on "The Fan."

The thrust per horse-power obtained with the best forms of propellers varies from 20 lb. to 60 lb., 40 lb. being the common maximum. The mechanical efficiency, as in the case of marine propellers, rarely rises above 50 per cent., the best results being obtained with a minimum of slip. This alone gives the aeroplane a superiority over the helicoptère.[1]

Stability of Gliders.

We have seen that the centre of pressure is ahead of the centre of area, and that the distance between these two depends on the angle γ. If then the angle and the normal pressure are constant, the turning moment of the pressure about the centre of area is also constant, and may be balanced by shifting the centre of gravity until it lies over the centre of pressure. Seeing, however, that neither the angle nor the resistance is absolutely constant, it might be supposed that stability was impossible. That this is not so has been demonstrated by Prof. Bryan and Mr. Williams in a paper read before the Royal Society in 1903, and by Captain Ferber in an article in the *Revue d'Artillerie* (November, 1905). In the latter it is shown that an aëroplane is longitudinally stable if two conditions are satisfied.

(1) That the longitudinal radius of gyration about an axis through the centre of gravity does not exceed

$$\sqrt{\frac{P}{37b}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

when P is the weight of the aëroplane in kilograms, and b the overall width of the machine in metres. The radius of gyration is here measured in metres.

(2) That the centre of gravity falls over the centre line between two points, one a little ahead of the centre of area of the sustaining surfaces, the other near the forward edge of the aëroplane. The exact values of these positions depend on the characteristic magnitudes of the machine through a series of somewhat complex equations, for which the papers referred to should be consulted. It must be recognised in this connection that the probable inaccuracy of Joëssel's formula invalidates the accuracy (*not* the method) of the values given by Captain Ferber in this paper.

If the centre of gravity coincide with one of these points, the machine is subject to two oscillations of long and short periods respectively, any increase of which will lead to collapse.

The behaviour of a machine running with a certain initial speed is then somewhat as follows. The continued resistance tends to retard the machine, and to cause the velocity to fall below the soaring limit, and the weight (in front of the centre of area) causes the front to dip. The gravitationally acquired velocity causes a forward acting pressure on the surface, so that if the machine is stable (in accordance with the above conditions), it settles down into a condition in which the resistance due to the resultant velocity just balances the component of the weight in the direction of motion. Pénaud has shown that the angle between the plane and the direction of motion (trajectory) (*l'angle d'attaque*) is half the angle between the trajectory and the horizontal when the trajectory is such as to give the greatest travel.

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[1] See the author's paper to the Aëronautical Society, October, 1908.

This condition is satisfied when

$$\tan \gamma = \sqrt{\frac{C}{2kS}} \quad . \quad . \quad . \quad [\text{see } (7)] \quad . \quad . \quad . \quad (14)$$

If from any cause the machine loses velocity, it will drop and gain kinetic energy by loss of potential, until its velocity is that required. On the other hand, if accidentally its velocity increases, it will rise, to lose kinetic energy by gaining potential energy. It is this exchange in the form of energy which causes the oscillations in an unstable glider. Prof. Bryan and Mr. Williams have photographed gliders bearing flash-lights, and demonstrated the reality of the long- and short-period oscillation, but the theory needs considerable amplification so as to apply to complex cases of combined planes, and simplification so as to be readily applicable to design.

Mr. Lanchester ("Aërial Flight," vol. ii., and British Association Trans., Dublin, 1908) gives new formulæ for the stability, and finds that the oscillations are trochoidal.[1]

Practice (Aëroplanes).

Time will not permit an exhaustive account of the theoretical principles involved to be given, but the more essential points have been touched upon, and it will be useful to indicate how these principles will be applied.

In designing an aëroplane the weight is perhaps the first consideration, and next the minimum velocity required. From formula (8) we can proceed to find S, the area.

$$W = 2kSV^2 \sin \gamma \cos \gamma \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Let $\cos \gamma = 1$, since γ is small, and $\sin \gamma = \frac{1}{3}$, and $2k = 0{\cdot}004$,[2] then

$$W = 0{\cdot}0012 \; SV^2,$$

and

$$S = \frac{W}{0{\cdot}0012 \; V^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Thus, if V is 30 feet per second (say thirty miles per hour), S = W, *i.e.* the area in square feet is the same as the weight in lb. Less area will necessitate more speed, and *vice versâ.*

A useful rule connecting the area and weight (based on bird flight in spite of dimensional theory) is that

$$S \propto W^{\frac{2}{3}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Next, to find the thrust required, we take formulæ (7) and (8), and get

$$\frac{T}{W} = \frac{R + CV^2}{W} = \tan \gamma + \frac{C}{2kS \sin \gamma \cos \gamma} \quad . \quad . \quad (17)$$

as the ratio between the thrust and the load. Neglecting the second term, which is small (or rather, taking a higher value for the first, so as to include the second), we write

$$\tan \gamma = \sin \gamma = \tfrac{1}{3} \text{ or } \tfrac{1}{4},$$

so that

$$T = \frac{W}{3 \text{ or } 4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Since the thrust per B.H.P. with a good propeller is about 30 lb. or 40 lb., we may write

$$40H = \frac{W}{4},$$

so that

$$W = 160H \quad . \quad . \quad . \quad . \quad . \quad (19$$

where H is now in B.H.P.

This may be regarded as a high value, and probably only half this can be safely employed, so that 1 horsepower will carry, say, 80 lb. Great improvements should eventually be made in this direction.

The light motors (such as the Antoinette, Dufaux, and Esnault-Pelterie types) now made produce about 1 B.H.P. per 3 lb. of weight, or allowing for transmission gearing and friction losses, say 1 B.H.P. per 5 lb. of mechanism, so that the weight of this will be = 5 H lb., and hence from (19) (modified as suggested) we get the available weight of the surfaces, framing, and aëronaut = 75 H lb., or for framing and surfaces alone (reckoning aëronaut's weight at 150 lb.)

$$W = (75H - 150) \text{ lb.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

Employing the rule obtainable from (15) that S = W we find the weight of surfaces and framing per square foot is

$$\frac{W}{S} = \frac{75}{80} - \frac{150}{S} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

Care must be taken to prevent surfaces interfering with one another, and this is generally attained by superposing them at a distance apart equal to their width, or placing them behind one another at the same minimum distance.

The positions of the aviator and the engines are very important. Generally the first is in front. The Wright machine has them side by side. In any case the position of the common centre of gravity must answer to the rules given in the theory of stability. Lateral balance is assured by the use of a dihedral angle between the wing planes or by a keel plane. Captain Ferber has discovered the laws controlling the size and position of the latter, which are to be found in the paper previously referred to. Steering is accomplished in several ways, as will presently be described.

Constructive Features.

Several types of machine may be distinguished, but three especially are noteworthy, and are named after their inventors :—(*a*) Chanute; (*b*) Langley; (*c*) Wright. The Phillips machine is a fourth type, but is analogous to the first. The *Chanute machine* is the type adopted by Farman, Delagrange, and Captain Ferber. It consists of two superposed, narrow surfaces mounted on a transverse girder. A central longitudinal girder connects this front frame with a rear one of similar form, but smaller, sometimes divided by partitions into cells after the pattern of the Hargrave kite. The aviator and motor are placed centrally at the rear of the front surfaces, where the c.g. must be, so as to be ahead of the mean centre of area of all the surfaces. The trimming planes are generally in front, and the steering planes at the rear. This differs, however, and will be discussed presently. One propeller is used between the sets.

The *Langley type,* generally termed monoplanar, consists of two pairs of wing surfaces, inclined 67½° from the vertical, so as to include a dihedral angle of 135°. A central shaft, or framed girder, supports the cantilever ribs which stay the wings. The engine is between the pairs of wings, and the two propellers are paired alongside.

Wright type.—Consists simply of two superposed surfaces as in the Chanute type, with no tail. Front trimming planes similar to the main wings, and rear vertical planes for steering. Catapult initial propulsion. Two propellers behind the wings.

Trimming and Steering.

Guide planes of various forms are used for trimming and steering. A cruciform set of planes for both purposes has been used on the Langley and Ludlow machines. Superposed pairs for trimming, placed in front, have been used by Farman, Delagrange, and the Wrights. Santos Dumont (xiv., *bis*) employed a cellular kite for both purposes, and M. Bleriot has used trimming planes, turning on axes, at the tips of the wing planes. A sliding weight is used in the Weiss gliders, and the author has suggested a weight on a coarse-pitched leading screw as useful. For steering laterally, vertical surfaces are generally employed at the rear. By slightly canting the machine a lateral thrust is produced which will turn the machine, although the consequent diminution in lift tends to make it lose elevation.[1] The Wrights also employ torsion of the main surfaces.

Starting and Alighting.

In starting an aëroplane there are numerous difficulties. The essential is that the soaring velocity shall be reached before the machine leaves the ground. If a machine be simply propelled along a track, so soon as the soaring velocity is approached the friction on the ground becomes negligible, and the propulsive effort is uncertain. Usually the machine rears or sinks forward, touches the ground, and loses its required velocity, so that no start is made. Langley experienced great difficulties in this way. Four methods are available.

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[1] See the *Engineer*, September 18, 1908.

[2] Twice 0·0017 (see p. 414) plus an addition of 0·0006 for the lateral spread generally employed.

[1] See paper by M. Renard in *Comptes rendus*, 1908.

(1) Starting on a track which the aëroplane cannot leave until the required velocity is reached. (Langley.)

(2) Starting on a track employing a small plane angle, and when a velocity has been reached in excess of the minimum for the machine, raise the planes quickly until the angle suits. The excess of speed will give the initial elevation required. (Farman, Delagrange, Ferber.)

(3) Start from a height, preferably down a slope. (Voisin, Roe.)

(4) Use a frame which can by the store of energy in springs, or a lifted weight, act as a catapult. (Wright Brothers.)

In each case the starting device (carriage, sledge, or catapult) may be integral with, or separate from, the machine. Separately, weight is, of course, saved. On the other hand, the machine is useless without the hoisting device. Starting-stages with necessary catapults or other devices have been suggested. The Aéro Club de France tests machines from a steel tower in the Galerie des Machines, on the principle given third in the foregoing list.

With regard to descent, this is intimately related to gliding stability. As we have seen, if the weight is in the right place, oscillations will be damped out, and the descending machine will follow a straight descending line with a uniform velocity. The alighting springs should be capable of storing the energy of impact corresponding to this speed and angle.

Helicoptères.

It will have become evident from what has been said that this type of machine is more or less at a discount. Machines have been made by Santos Dumont, Kress, Dufaux, and others, but as yet the results are not very important. The ability to soar is undoubtedly a great advantage, but the loss due to insufficient air supply, the absence of wedge action, and the necessity for further machinery to give lateral propulsion are great drawbacks. Mr. Rankine Kennedy is one of the strongest advocates of this type just now, and is evidently convinced as to its ultimate success. The author has interested himself in the type for a long time, but cannot say that at present he considers it to be superior to the aëroplane. In a paper just presented to the Aëronautical Society he has discussed the question.

Ornithoptères.

Profs. Marey and Pettigrew have shown that the wings of flying animals rotate while reciprocating, so as to provide a forward thrust as well as a downward one. (See "The Problem of Flight," p. 59.) The researches of Mouillard, Langley, Fitzgerald, and Deprez have also shown how the greater flying birds manage to utilise the pulsations of the wind and its vertical component to soar and glide. Lord Rayleigh has given simple rules in this connection.

A type not uncommon (on paper) is the rotating machine, in which a number of blades are controlled by a cam, so that on the downstroke they move perpendicular to their planes and on the upstroke parallel to their planes, and thus produce an upward resultant thrust. The mechanical efficiency of such an arrangement cannot be so high as that of an aëroplane. Moy's aërial steamer and centrifugal fan types correspond to this variety.

Future Work.

Reference has been made to the necessity for further research as to the centre of pressure. Information is also wanted as to the resistance and stability of combined planes, the thrust of screw propellers, and the effect of lateral currents on propellers and gliders. The mathematical analysis of the equations of motion of the aëroplane in space needs to be advanced. Simpler forms of the equations of stability and trajectory are required. The application of the latest investigations as to resistance (such as M. Eiffel's) and centre of pressure to these equations has yet to be made, and bird flight needs much study by ornithologists trained in applied mechanics.

Relation to War and Commerce.[1]

The sudden development of aërial navigation led to a popular panic which was quite baseless. At present the dirigible balloon is extremely vulnerable, cannot carry more than a few pounds' weight of projectiles, and has great difficulty in hitting a mark. In espionage it may be useful. Aëroplanes may perhaps be presently available for attacking vital points and despatch work, but it will be long before they will be steady in a wind.

Commercially, the outlook is worse. Although the energy required for aërial transport is not much greater than in terrestrial and marine locomotion, the danger and unpunctuality will take many years to eliminate. Wind occasionally (not frequently) will have serious effects on direction and time of passage. Eventually the airship and flying machine will affect society, but the author thinks it will not be for some years to come.

Finally, the author wishes to point out the deplorable backwardness of English invention in this direction.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The following programme for the Darwin centenary celebrations, subject to alteration in detail, will be issued at an early date:—

Tuesday, June 22.—8.30 p.m. to 11 p.m., reception of delegates and other invited guests by the Chancellor in the Fitzwilliam Museum. By kind permission of the master and fellows, the gardens of Peterhouse will be accessible from the museum.

Wednesday, June 23.—10.30 a.m., presentation of addresses by delegates in the Senate house; 2.30 p.m. to 3.45 p.m., visits to colleges; 4 p.m., garden-party given by the master and fellows of Christ's College in the college grounds; 7 p.m., banquet in the new examination hall; 10 p.m. to 12 p.m., the Vice-Chancellor and fellows of Pembroke College "At Home" in the college hall and gardens.

Thursday, June 24.—11 a.m., honorary degrees conferred in the Senate house; 12 a.m., Rede lecture in the Senate house by Sir Archibald Geikie, president of the Royal Society.

A Darwin exhibition will be held in Christ's College on the lines of the Milton exhibition of last year. The syndics of the University Press have agreed to present to each invited guest a copy of the first draft of "The Origin of Species," which is being prepared for press and edited by Mr. Francis Darwin. This is the draft of which Mr. Darwin speaks in his autobiography:—"In June, 1843, I first allowed myself the satisfaction of writing a very brief abstract of my theory in pencil in thirty-five pages."

It is proposed to prepare an illustrated programme of the commemoration containing some account of Darwin's Cambridge days, under the editorship of the registrary, the senior secretary to the celebration committee.

Of the seventeen colleges, fifteen have now published the results of their entrance scholarship examinations. The number of scholarships has slightly increased, and in natural sciences seven and a half more scholarships have been awarded this year than last. The mathematical scholarships are fewer by the same number; the half represents a scholarship which has been awarded partly for natural sciences and partly for some other subject. There is also an increase of four in the history scholarships. Out of the 201 scholarships, 74 have been awarded for classics, $43\frac{1}{2}$ for natural sciences, and $35\frac{1}{2}$ for mathematics. Only eight candidates availed themselves of their privilege of resigning their emoluments whilst retaining the status of a scholar.

The special board for biology and geology has appointed Mr. J. Stanley Gardiner, of Gonville and Caius College, to be a manager of the Balfour fund until June 14, 1911, in succession to Dr. Harmer, who has resigned.

Mr. David Sharp has resigned the curatorship in zoology from March 25, 1909, and Mr. Hugh Scott, of Trinity College, has been appointed in his stead for one year from March 25, 1909.

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[1] See article by Prof. Newcomb in the *Nineteenth Century*, September 1908.